

Performance Evaluation of AGNPS Model on Steep Slopes by means of GIS

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Abstract:

Non-point source pollution has become a significant topic for several researches and these researches have revealed numerous models and modeling techniques. In this study, commonly used rainfall-runoff-erosion model (AGNPS-Agricultural Non-Point Source Pollution Model) was examined to investigate its applicability on steep slopes. The use of GIS to improve the efficiency of the model was also considered. The data collected for this study were from the Guvenc basin which covers an area of about 16 km² in Ankara, Turkiye. It has a high slope (up to 49 %) and sediment yield ratio (35.83 t/ha/year) compared with Turkiye's average of 2.18 t/ha/year. The annual average rainfall is 562 mm, with an average temperature of 11.7 °C, and relative humidity of 62 percent.

The Guvenc basin was divided into 52 subbasins by GIS software considering topography. Beside determination of watershed area and subbasin boundaries, also contributing cell, subbasin which cell includes, cell area, average elevation, slope, aspect, topographic factor, flow length, flow slope, concentrated slope and concentrated length was determined by GIS. Model predictions were compared with measured data between years of 1997 and 2000. During this period annual average rainfall was 562.3 mm and surface runoff was 176.7 mm. AGNPS, predicted 166.5 mm surface runoff at that time period.

Key words: AGNPS version 2001, GIS, Guvenc basin, runoff, steep slope, topography

Introduction

Non-point source pollution (NPS) has become a significant topic for several researches and these researches have revealed numerous models and modeling techniques. Most models simulate hydrologic, chemical, and physical processes involved in the entrainment and transport of water, sediment, nutrients, and pesticides due to rainfall in catchments and basins (Yu, 2000; Leon et al., 2001).

Runoff and erosion occur in cases where the amount and intensity of rainfall is higher than the infiltration rate and capacity of the soil. Runoff causes soil and nutrients to be carried away, and dead storage of dams to be filled. Water quality is also decreased when chemicals and fertilizers are carried away. Although contaminated urban or industrial sources can be determined by point measuring in urban basins, erosion and pollution can not be measured easily in precipitation, runoff, or agricultural applications in rural basins. Researchers interested in basin management have developed models to simulate the relationship between precipitation, runoff, and erosion.

The main purposes for studying models are: (1) to be able to express basic data of complex and interactive events, (2) to acquire needed data in ungauged basins, (3) to achieve results quickly and easily by eliminating unnecessary time and expense, and (4) to arrive at different possible alternatives. Besides all of these advantages, sometimes, unacceptable differences may occur between measured values and model results. These differences may increase in cases where the factors significantly effecting runoff such as steep slopes exhibit great variations from the average values.

A number of model validation and comparison studies are presented in the literature. Young et al. (1989), creators of AGNPS, found a regression equation which has a coefficient of determination of 0.81 from twenty different basins located in the North-Central United States.

Bingner et al. (1989) compared CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems), SWRRB, EPIC (Erosion Productivity Impact Calculator), ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation) and AGNPS (Agricultural Non-Point Source Pollution Model) in three Mississippi basins. Results showed that none of the models worked

well in every situation of basin runoff and sediment yield.

Mitchell et al. (1993) used AGNPS and GRASS (Geographic Resources Analysis Support System) GIS to predict runoff and sediment delivery of small basins. Fifty sediment yield events were monitored from two basins in East-Central Illinois throughout the growing seasons of four years. They simulated 13 mm mean runoff in Allerton Basins, although the observed value for twenty-five different events after calibration was 7 mm.

Wu et al. (1993) evaluated AGNPS, ANSWERS and CREAMS for three basins in thirty events. The median ratios of computed to measured runoff for the three basins were between 0.3 and 1.2. The ratios of computed to measured sediment yield were between 0.5 and 2.0. The most suitable estimations were made by ANSWERS.

By means of GIS, the AGNPS model was used to assess runoff, soil erosion and non-point source pollution for events monitored in the Alpone Watershed in Italy. Researchers found that the difference between the average measured and average predicted runoff values and sediment values were 6 percent and 26 percent, respectively (Lenzi and Luzio, 1997).

Turkelboom et al. (1997) determined tillage erosion rates on steep slopes. On slopes up to 60%, there were no significant differences in soil fluxes. However, on slopes steeper than 70%, soil fluxes increased significantly because the angle of repose for soil clods was exceeded.

The AGNPS model was tested to evaluate its applicability and performance with respect to hydrologic conditions by Perrone and Madramootoo (1999). An average error of 28.2 percent and a 0.001 coefficient of performance were observed in predicted sediment yield values.

Hessel et al. (2003) conducted an experimental research for a range of land uses as well as for different slope angles (6–64%). For croplands, there was an apparent linear increase in Manning's n with increasing slope angle ($R^2 = 0.70$). The trend of Manning's n with slope implies that, in soil erosion models using Manning's equation, the value of n should be a function of the slope for erodible soils.

Govindaraju (1995), Tucker et al. (2001), Asano et al. (2002), Uchida et al. (2006) Onda et al. (2006) and Tani (1997) carried out researches to determine the effects of topography on hydrological processes.

Modeling studies of rainfall - runoff and non-point source pollution had a great speed during the last decade due to developed computer models. Main handicap at that point: suitability of a model for different conditions (i.e. location, soil, weather, crop, topography and farmer conditions) is an enigma. As mentioned above, some models displayed reasonable results in some situations, whereas the others did not. Usually, models are developed around the average values to receive a global attention or to be used globally. They can result in significantly different outcomes under conditions varying greatly from the average conditions. In order to determine the validity of models, studies should be conducted under different conditions. Our primary goal is to determine which combination of model and watershed conditions perform at acceptable limits on steep slopes. In this study, results of commonly used rainfall-runoff-erosion model (AGNPS) was evaluated for Guvenc Basin in Turkey.

Research area

The data collected for this study were from the Guvenc basin in Ankara, Turkey (Figure 1). The study area covers an area of about 16 km². It is located at 42° 08' 00'' north latitude and 32° 45' 15'' east longitude. The Guvenc basin has a high slope (up to 49 %) and sediment yield ratio (35.83 t/ha/year) compared with Turkey's average of 2.18 t/ha/year (Yalcin et al., 2001). Its discharge point has an elevation of 1053 meters and discharged into a lake. Summer months in this region are hot and dry, while winter months are cold and rainy. Measured rainfall, water discharge data were obtained from General Directorate of Rural Services. Rainfall was measured by five pluviograph and water discharge was measured by a limnigraph at outlet point. The annual average rainfall is 562.3 mm, with an average temperature of 11.7 °C, and relative humidity of 62 percent. The highest average amount of monthly rainfall was 72.8 mm in April, while the lowest was 13.0 mm in November. The soil texture generally contains clay loam and silty loam, has a saturated conductivity ranges from 4 to 37.4 mm/h,

organic matter of 1 – 4.44 percent, the USLE K factor is 0.18-0.48, field capacity is 0.27-0.38 m/m and the permanent wilting point is 0.13-0.27 m/m. Wheat (33%), pasture (51%), and vineyards (16%) are found in this region. Soil and water conservation practices have been in use since 1984 (Denli, 1997; Demirkiran, 1997; Tekeli and Babayigit, 2003).

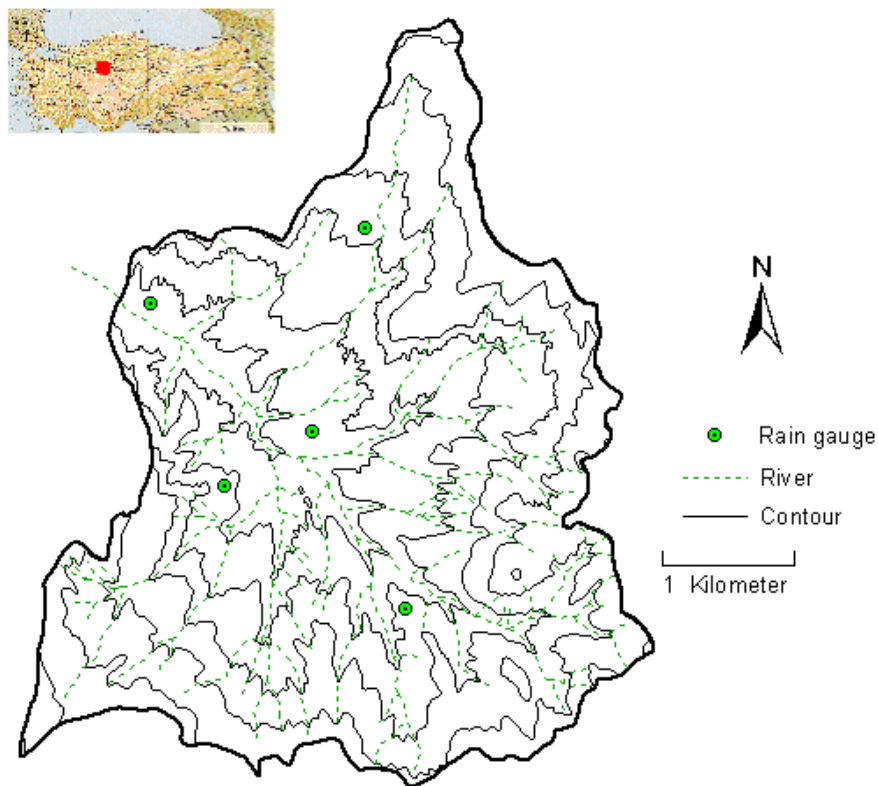


Figure 1. Ankara-Yenimahalle-Guvenc basin

Model: AGNPS (Version 2001)

Agricultural Non-Point Source Pollution Model (AGNPS) was developed to analyze non-point source pollutant loadings in agricultural basins. AGNPS is a result of a joint effort between the United States Department of Agriculture – Agricultural Research Service (USDA-ARS) and the Natural Resources Conservation Service. Version 5.0 of AGNPS is useful for basins up to 20 000 ha with cell sizes of 0.4 ha to 16 ha. This model uses (1) hydrology, (2) erosion and sediment yields, (3) chemical transport, and (4) point source submodels (Young et al., 1989). With AGNPS version 2001, which was used in this study, a year or a period may be simulated, not just a single-event. Runoff was calculated using Curve Number (CN), which was developed by the Soil Conservation Service (SCS). Sediment yield was calculated using the Revised Universal Soil Loss Equation (RUSLE) in AGNPS 2001 (Bingner et al., 2001).

Laboratory and Office Research

Soil structure, wilting point, field capacity, saturated conductivity, specific gravity, and organic matter for models were analyzed (Table 1) in a laboratory using methods described in Carter (1993) and Okman (1998). Manning's *n* values were obtained from Hessel et al. (2003) for each slope. Estimated runoff values by models were compared with measured values and a *t*-test was performed, as well (Haan, 1979; Maidment, 1992).

Errors were calculated as 'actual minus predicted' and the mean of these errors was calculated in 4 ways: mean error (ME), indicating the degree of bias; mean absolute error (MAE), providing a measure of how far the estimate can be in error, ignoring its sign; mean relative error (MRE), providing a measure of how far the estimate can be in error relative to the measured mean; root mean square error (RMSE), providing a measure that is sensitive to outliers. It is desired that all the error terms should be kept at minimum levels.

Table 1. Properties of soil samples

Sample no	Saturated conductivity (mm/h)	Organic matter (%)	Sand (%)	Clay (%)	Silt (%)	Soil texture	K factor of USLE	Weight density (gr/cm ³)	Field cap. (m/m)	Wilting point (m/m)
1	13.30	2.43	24.02	30.92	45.06	clay loam	0.23	1.47	0.34	0.20
2	18.65	1.84	11.27	42.67	46.06	silty clay	0.25	1.48	0.37	0.27
3	3.98	1.62	14.08	16.28	69.65	silty loam	0.48	1.52	0.38	0.18
4	32.11	1.58	40.11	24.04	35.85	loam	0.24	1.57	0.27	0.13
5	11.54	1.77	23.38	19.07	57.55	silty loam	0.38	1.55	0.34	0.15
6	25.12	1.35	24.40	40.46	35.14	clay loam	0.21	1.58	0.35	0.21
7	20.70	0.96	19.50	19.00	61.49	silty loam	0.44	1.54	0.36	0.12
8	37.39	1.53	32.53	29.13	38.35	clay loam	0.25	1.60	0.33	0.25
9	12.66	2.12	16.83	24.55	58.61	silty loam	0.32	1.53	0.35	0.14
10	17.43	1.96	17.97	38.18	43.86	silty clay loam	0.22	1.39	0.36	0.20
11	16.25	1.14	23.74	38.72	37.54	clay loam	0.18	1.62	0.33	0.22
12	15.82	1.43	21.25	35.65	43.10	clay loam	0.27	1.62	0.32	0.24
13	19.41	1.56	22.27	32.92	44.82	clay loam	0.22	1.57	0.33	0.20

Comparison of the estimated and measured daily stream flow was also carried out based on the model efficiency (EF), defined below (Nash and Sutcliffe, 1970):

$$EF = 1 - \frac{\sum_{i=1}^n (O_i - P_i)^2}{\sum_{i=1}^n (O_i - \bar{O})^2}$$

Where;

\bar{O} is the mean observed daily stream flow,

O_i is the observed stream flow at day i ,

P_i is the simulated stream flow at day i and

n is the number of days. The optimal value of the model efficiency is 1.

Data derived from GIS

AGNPS require not only general data (topography, land use, soil, etc.), but also specialized data (channel slope, soil water content, saturated conductivity, etc.). Such spatial and topographical data are not easily extracted without GIS. ArcInfo 8 and TOPographic PARAMeterization (TOPAZ) GIS software were used in this study as well (Garbrecht and Martz, 1997; ESRI, 2001). Contours were digitized from 1/25 000 scale maps in vector format with a 10 m elevation difference. The vector data was then converted to a Digital Elevation Model (DEM) for TOPAZ, which has a resolution of 15 m. Using GIS softwares, basin and subbasin boundaries were extracted automatically. Finally, slope, flow, aspect, and three-dimensional elevation maps were generated. Land use and soil maps were also digitized and prepared for spatial analysis in subbasins. For this reason, details concerning which data were used by which models are included below.

After the basin was divided into subbasins, data related to climate, soil, land use, and crop were entered into AGNPS. Since there is a data transfer function between TOPAZ and AGNPS, subbasins created in TOPAZ were automatically transferred to AGNPS. TOPAZ divided the Guvenc basin into 52 subbasins. In addition, subbasins where flow had begun were divided into three parts: source, left, and right. As a result, the Guvenc basin was divided into a total of 126 cells (Figure 2). TOPAZ automatically extracted the flow reach location, average elevation, slope, and length for each of the 52 subbasins. It also automatically extracted the cell-reach identifier, subbasin, cell area, time of concentration, average elevation, average land slope, aspects of the RUSLE/USLE LS factor, sheet flow slope and length, and concentration flow slope and length from DEM for each cell. Soil properties and land use data were extracted by overlaying soil, land use, and cell maps using ArcInfo.

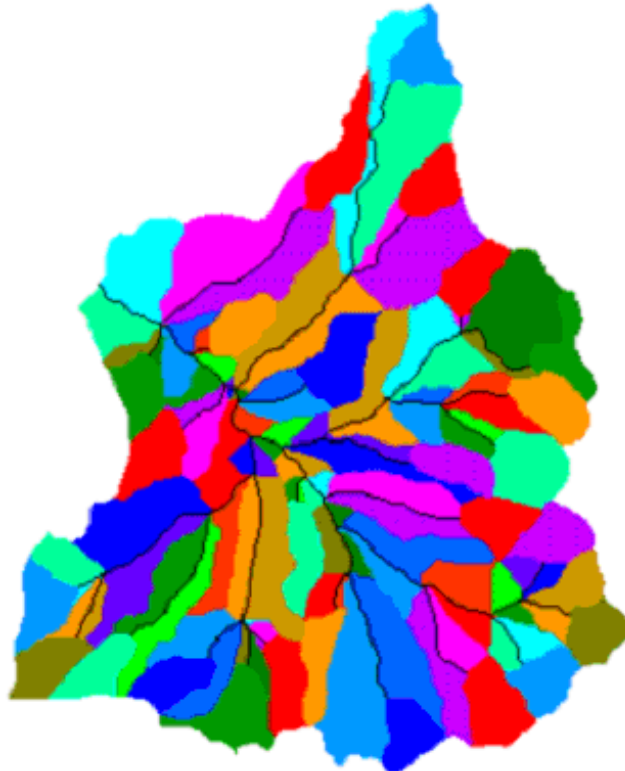


Figure 2. Dividing of basin into 126 cells for AGNPS model

Results and discussion

Runoff results

AGNPS is able to estimate runoff on a daily, monthly, or yearly basis. The simulation period chosen for this study was from January 1996 to December 2000. There are several significant coefficients in runoff estimation related land and climate conditions. Calibrations should be carried out for the best selection of these coefficients under prevailing conditions (Apaydin et al., 2006). Therefore, the first year of the simulation was used for calibration (January 1996 to December 1996). Calibration on basin discharge was done by using the discharge peak followed by an adjustment for the total discharge to obtain the correct amount. For the calibration period of with 159 mm runoff, relatively closer results to measured annual values were obtained (Table 2). Runoff estimations of AGNPS and errors for the calibration period were 162.2 and 3.2 mm (2 %) respectively. This small error indicates the success of calibration process.

The lowest elevation of the basin is 1053 m and the highest elevation is 1459 m. Between the two points, 406 m elevation difference creates significant changes in climate parameters of the basin. To adopt these local changes into models, climate factors were interpolated into the basin by using simple cokriging method recommended in Apaydin et al. (2004). A 10-20% performance increase was achieved with this process.

From January 1997 to December 2000, 2249.4 mm rainfall and 707.0 mm surface runoff were measured. As shown in Table 2, simulated results were 666.2 mm by AGNPS. The highest measured runoff occurred in 1998 (239.7 mm) similarly AGNPS (204.5 mm) produced the highest total runoff in 1998. The lowest measured runoff occurred in 2000 (132.9 mm); AGNPS (134.0 mm), produced the lowest total runoff in 2000. During this period, the least errors were obtained from AGNPS with 0.8% in the year 2000. Although the year 1998 had the highest rainfall, the lowest runoff was observed during the same year. Therefore, the highest error rate was observed during this year (-14.7%). Based on 4 years average values, model was revealed the error rates of -5.8%.

Table 2. Monthly and yearly measured precipitation, runoff and predicted values

Month/Year	Measured precipitation (mm)	Measured runoff (mm)	Predicted runoff values (mm)	Differences from measured (mm)
1/1996	29.5	11.3	11.3	0.0
2/1996	61.2	22.9	20.6	-2.4
3/1996	71.8	38.6	31.9	-6.7
4/1996	41.6	40.5	30.8	-9.6
5/1996	99.1	21.5	22.2	0.7
6/1996	6.0	7.9	6.4	-1.4
7/1996	8.3	2.3	3.9	1.6
8/1996	29.0	0.1	4.2	4.1
9/1996	79.6	2.1	8.8	6.7
10/1996	61.3	1.6	6.1	4.5
11/1996	14.5	1.8	2.9	1.1
12/1996	100.6	8.5	13.1	4.6
1996 (Calibration)	602.6	159.0	162.2	3.2 (2.0 %)
1/1997	49.3	13.6	15.8	2.2
2/1997	21.3	8.8	8.9	0.1
3/1997	26.7	8.3	11.0	2.7
4/1997	122.3	49.4	39.6	-9.9
5/1997	44.8	29.7	19.2	-10.4
6/1997	62.8	13.1	13.0	-0.1
7/1997	12.3	4.8	8.2	3.4
8/1997	53.3	2.2	7.1	4.9
9/1997	0.0	0.3	3.2	2.9
10/1997	97.8	2.1	8.9	6.7
11/1997	55.8	5.6	8.5	2.9
12/1997	110.2	23.2	23.0	-0.2
1997	656.5	161.1	166.4	5.3 (3.3 %)
1/1998	20.0	16.8	13.8	-3.0
2/1998	51.3	42.3	26.8	-15.5
3/1998	51.6	32.9	24.3	-8.6
4/1998	74.9	44.4	32.4	-12.0
5/1998	136.2	49.3	35.5	-13.8
6/1998	50.2	33.6	22.1	-11.5
7/1998	12.8	9.0	9.4	0.4
8/1998	0.0	2.1	7.3	5.3
9/1998	29.2	0.6	7.7	7.2
10/1998	21.5	0.9	8.7	7.9
11/1998	48.4	2.0	8.2	6.2
12/1998	65.9	6.0	8.2	2.2
1998	562.1	239.7	204.5	-35.2 (-14.7 %)
1/1999	56.1	4.8	8.1	3.3
2/1999	126.1	37.9	31.5	-6.4
3/1999	75.4	55.0	34.0	-21.0
4/1999	30.7	40.0	24.9	-15.1
5/1999	19.2	14.6	12.8	-1.7
6/1999	51.3	7.9	7.9	0.0
7/1999	71.1	4.5	8.8	4.2
8/1999	44.4	1.7	6.4	4.8
9/1999	20.6	0.3	4.9	4.6
10/1999	45.1	1.7	6.5	4.8
11/1999	25.0	0.7	6.8	6.1
12/1999	65.0	4.3	8.7	4.4
1999	630.0	173.3	161.3	-12.0 (-6.9 %)
1/2000	54.4	6.2	6.4	0.2
2/2000	30.5	10.4	10.1	-0.2
3/2000	49.8	39.0	27.7	-11.3
4/2000	63.0	40.4	28.6	-11.7
5/2000	40.9	22.0	16.0	-6.0
6/2000	50.3	11.2	11.7	0.5
7/2000	0.0	2.8	5.6	2.8
8/2000	35.5	0.0	4.8	4.8
9/2000	2.2	0.0	4.0	4.0
10/2000	0.0	0.0	4.8	4.8
11/2000	33.7	0.1	7.4	7.3
12/2000	40.4	0.9	6.8	5.9
2000	400.8	132.9	134.0	1.1 (0.8 %)
Total (1997-2000)	2249.4	707.0	666.2	-40.8 (-5.8 %)
Mean (1997-2000)	562.3	176.7	166.5	-10.2 (-5.8 %)

Over the four-year period, there was an annual average of 562.3 mm rainfall and 176.7 mm runoff. Simulated yearly runoff figures were 166.5 mm by AGNPS, (Table 3). Corresponding to the measured rainfall of 46.9 mm and runoff of 14.7 mm, model runoff estimation was 13.9 mm. While the model resulted in over estimated values during the calibration year (1996), it was resulted in smaller estimations than the measured ones for 1997-2000 period.

Table 3. Monthly mean precipitation and runoff values between 1997-2000

Months	Measured precipitation (mm)	Measured runoff (mm)	AGNPS
I	45.0	10.3	11.0
II	57.3	24.8	19.3
III	50.9	33.8	24.2
IV	72.8	43.5	31.3
V	60.3	28.9	20.9
VI	53.7	16.5	13.7
VII	24.0	5.3	8.0
VIII	33.3	1.5	6.4
IX	13.0	0.3	5.0
X	41.1	1.2	7.2
XI	40.7	2.1	7.7
XII	70.4	8.6	11.7
Total	562.3	176.7	166.5
Mean	46.9	14.7	13.9

As it can be seen clearly from Figure 3, showing the difference between measured monthly values and estimated values, model has revealed relatively closer results, however there is a deviation from the measured values. This deviation can be better seen in Table 3. Based on measured monthly values, the highest runoff was observed in April with 43.5 mm and the model has estimated the highest runoff values for the same month but the difference between the measured and estimated values was around 12 mm (25 %). While the lowest average runoff was observed in September with 0.3 mm, model has revealed significantly different value as around 5 mm. When the results were examined, it can be seen that the model usually resulted in underestimated runoff values under high rainfall conditions and overestimated values under low rainfall conditions. Model generally overestimated runoff in August, September, October, November and December, and underestimated runoff in February, March, April, May and June (Figure 3 and Table 3). In spite of monthly differences in a year, annual average and long-term monthly average values are relatively closer to the measured values. Due to models produced flexible results for entire research period, analyzes were renewed deeply. It might be more meaningful to analyze results on the basis of growing season and the season of the year.

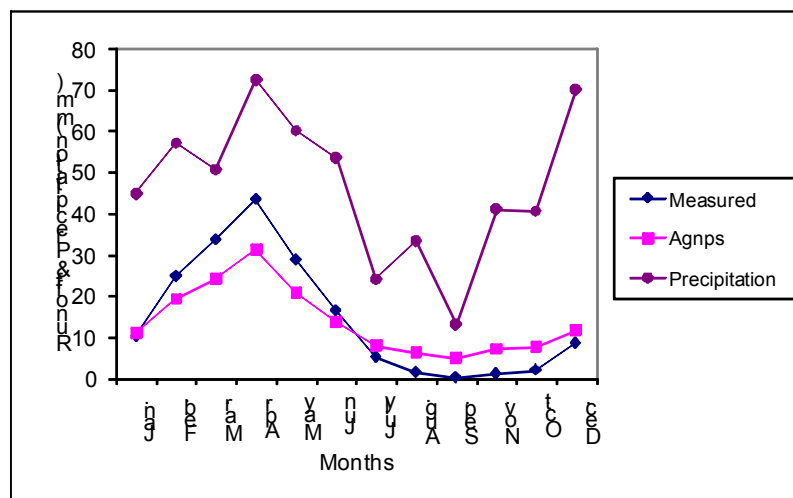
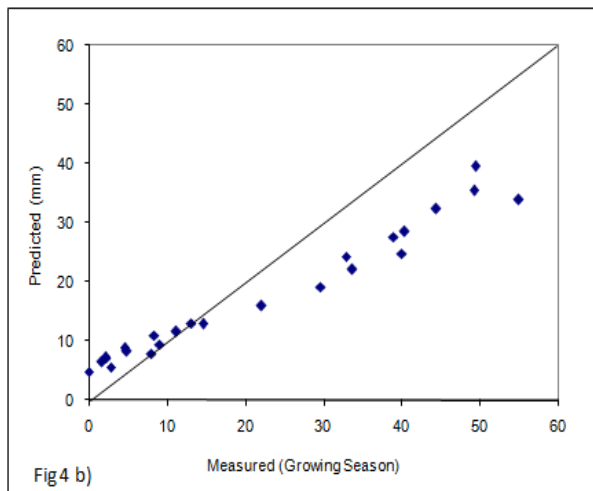
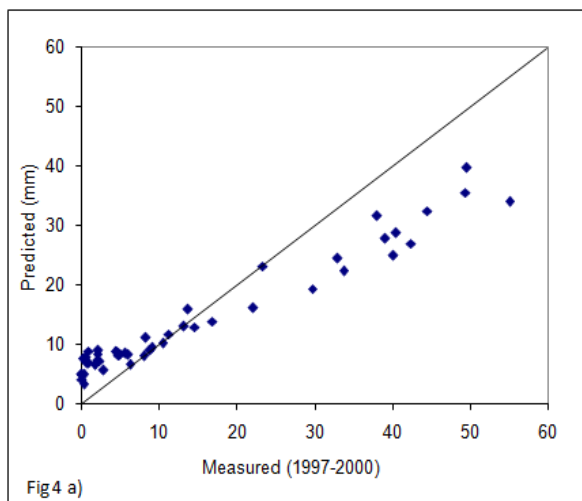


Figure 3. Measured versus predicted monthly runoff values for each of the models

Monthly measured values for 1997-2000 period and estimated values of the model were given in Figure 4a. While the model estimated higher values than measured ones when the monthly values are lower than 10 mm, it estimated lower values when the monthly values are higher than 10 mm. Beside this, estimations exhibited a linear distribution.

Comparison of measured and estimated values for the growing season (March – August) of the period 1997-2000 (Figure 4b) are relatively similar to Figure 4a taking the entire year into consideration. As it can be seen from Figure 4c, taking only the fall seasons into consideration, the model-estimated values were higher than the measured values. Although there were not any runoff in some fall months, models have estimated runoff values of 3-8 mm. Points form a cluster in this interval.

As seen in Figure 4c, taking the winter months into consideration, distribution is similar to the one obtained for growing season. Model estimated higher values than the measured ones under 10 mm. Contrary to fall season, model estimations were lower than the measured ones for spring months (Figure 4c).



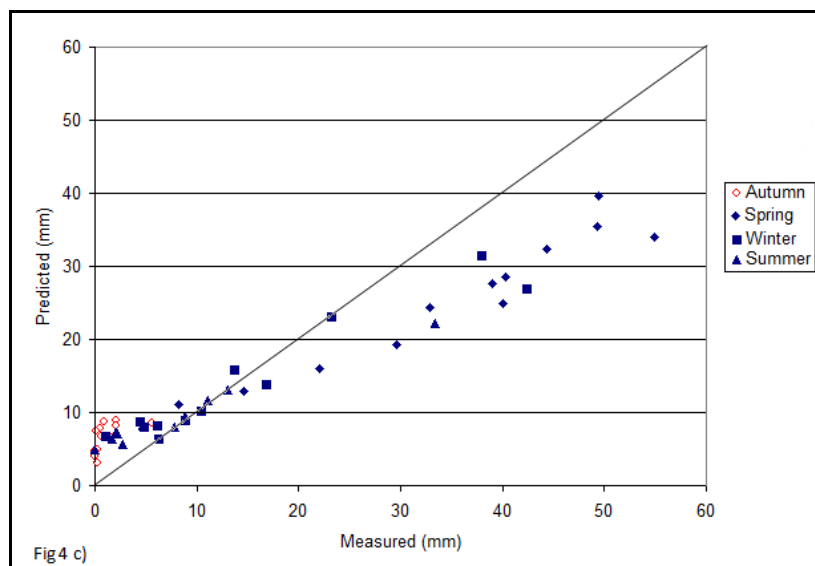


Figure 4. Monthly mean measured and predicted values

Very low runoff levels were observed during the summer months and models have revealed higher estimations than the measured values. Seasonal estimations given in Figures 4c exhibit parallel outcomes with Figure 3 giving the monthly changes.

For the quantitative evaluation of the results given thus far, daily, monthly and annual-based t-test results, ME, MAE, MRE, RMSE and EF coefficients were given in Table 4. T-test results may be misleading in some cases since they take the deviations from the means of measured values into consideration. On the other hand, ME may result in erroneous values in calculating the difference of estimated values from the measured ones in cases where positive and negative differences balance each other. Therefore, MAE, MRE, RMSE and EF values were taken into consideration in model evaluations and p and ME values were used only used as supportive data.

Table 4. t, error and EF values of daily, monthly and yearly basis

Period	Interval	t*	P	ME	MAE	MRE	RMSE	EF
1996 (Calibration)	Daily	-0.24	0.81	-0.01	0.22	2.03	0.31	0.64
	Monthly	-0.05	0.96	-0.27	3.62	4.7	4.59	0.89
1997- 2000	Daily	1.22	0.22	0.03	0.3	4.82	0.44	0.56
	Monthly	0.3	0.76	0.85	5.76	3.63	7.39	0.8
	Yearly	0.38	0.72	10.2	13.41	0.06	18.8	0.77
Growing season (March to August)	Daily	3.95	0	0.13	0.35	1.14	0.47	0.55
	Monthly	0.95	0.35	4.14	6.96	0.59	8.81	0.76
Autumn	Daily	-9.87	0	-0.18	0.21	15.15	0.35	-8.09
	Monthly	-7.48	0	-5.45	5.45	12.53	5.69	-13.01
Winter	Daily	0.4	0.69	0.02	0.31	1.94	0.45	0.55
	Monthly	0.13	0.9	0.58	3.64	0.81	5.52	0.82
Spring	Daily	6.58	0	0.32	0.45	0.46	0.57	0.32
	Monthly	2	0.06	9.91	10.36	0.29	11.53	0.31
Summer	Daily	-1.91	0.06	-0.05	0.25	1.81	0.36	-0.06
	Monthly	-0.55	0.59	-1.63	3.57	0.9	4.73	0.71

* t : Student-t results, P : Probability, ME: Mean error, MAE: Mean absolute error, MRE: Mean relative error, RMSE: Root mean square error, EF: the model efficiency defined by Nash and Sutcliffe. The Lowest, MRE, RSME and the highest P, EF values are in bold.

Evaluations of usage of GIS and models

In basin scale study, data (rainfall, runoff, soil, topography, land cover and use, soil water content, etc.) are very difficult to collect due to area size. It is here that remote sensing and geographic information system are vital, assisting in the collection of data for a large surface area. Current basin

data are easily and quickly collected by remote sensing compared with conventional methods. GIS has an important role in data processing related topography and some formulation. Model developers added both technologies to their own models to use this advantage. So, model development and testing is usually undertaken by interdisciplinary teams that attempt to link the quantity, timing, and quality of water to land use and watershed characteristics.

Compared with conventional methods, the area, average slope, average elevation, distance to basin outlet, aspect, flow length, and USLE LS factor for each cell (or subbasin) are quickly and easily determined using ArcInfo and TOPAZ. Land use and soil properties are determined for each cell or subbasin, but only one value is extracted for the entire cell by generalization in ArcInfo.

Conclusion

To increase the confidence in the use of a model, researchers, managers and developers need to evaluate its predictive performance. In this study, relationship between rainfall and runoff on steep slopes are examined. Taking the seasons into consideration, the best estimations were achieved in winter months and the worst in fall months.

For basins with significantly changing topographies in land slopes and elevations, changes in climate parameters with location and elevation should definitely be taken into consideration to increase the model performances.

GIS was very profitable for topographical and spatial data extraction and recognition. Without the use of GIS software, especially TOPAZ, application of the AGNPS model would have been impossible. AGNPS requires a lot of parameters such as reach identifier, reach location code, area, average elevation, land slope, aspect, USLE LS factor, concentrated flow length etc for each cell. Determination of them traditionality takes much time and increase possibility of error. Spatial data like land use and soil properties are easily extracted from entire map and then only one value is calculated for each subbasin or cell in all three models.

GIS will be more developed, easy to use, less expensive and finally have more usability depending on development of computer hardware and software. At that point, software developers and experts in certain topic should done multidiscipline studies, they must create or rebuild softwares for data acquire to models.

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